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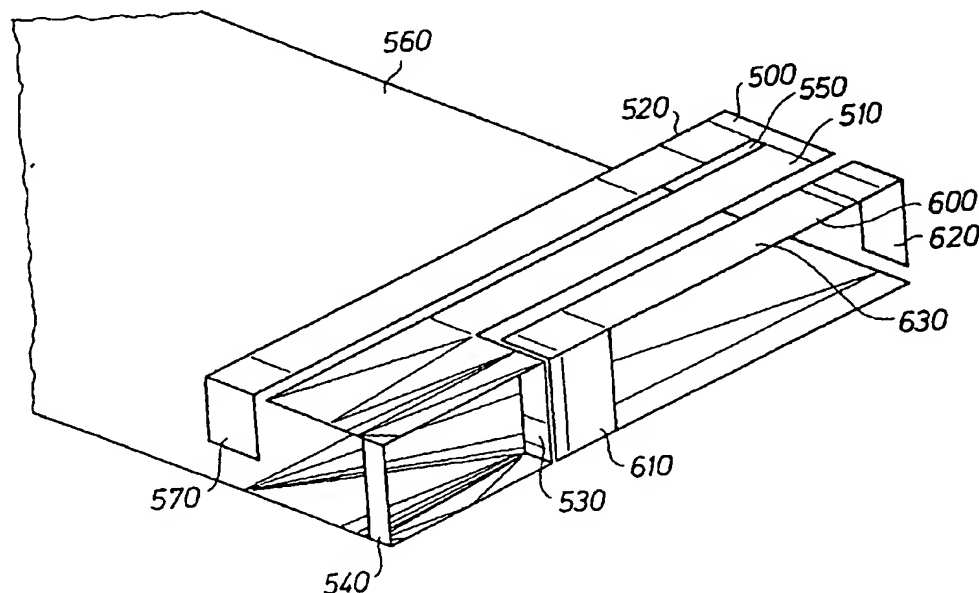
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(54) Title: ANTENNA



(57) Abstract: The present invention relates to a built-in folded PIFA antenna for a radio communication device (400, 450) and a mobile phone (400) containing the same antenna. The built-in antenna comprises a first part (500) tuned to a first and a second frequency band, and a second part (600) electro-magnetically interacting with the first part (500) and galvanically separated from the first part. While the second part (600) interacts with the first part, the antenna is tuned to a third frequency band. The first part (500) is folded to form a first element (510) and a second element (520), wherein the second element (520) is folded approximately 180 degrees in relation to the longitudinal axis of the first element (510).

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Antenna

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Field of invention

The present invention relates to a communication device in a radio communication system, and a built-in antenna for a radio communication device.

15 Related applications

This application is related to U.S. Patent Application No. 09/112 366 filed July 9, 1998, and entitled "Miniature Printed Spiral Antenna for Mobile Terminals", U.S. Patent Application No. 09/112 152, filed July 9, 1998 and entitled "Twin Spiral Dual Band Antenna" and U.S. Patent Application No. 09/212 259, 20 filed December 16, 1998, and entitled "Printed Multi-Band Patch antenna", all of which are incorporated by reference in their entireties herein.

Background of the invention

The present invention relates generally to radio communication systems 25 and, in particular, to built-in antennas which can be incorporated into portable terminals and which allow the portable terminals to communicate within different frequency bands.

The cellular telephone industry has made phenomenal strides in commercial operations in the United States, Europe and the rest of the world. Growth in 30 major metropolitan cities has far exceeded expectations and is rapidly outstripping system capacity. If this trend continues, the effects of this industry's growth will

5 soon reach even the smallest markets. Innovative solutions are required to meet these increasing capacity needs as well as maintain high quality service and avoid rising prices.

Throughout the world, one important step in the advancement of radio communication systems is the change from analogue to digital transmission.

10 Equally significant is the choice of an effective digital transmission scheme for implementing the next generation technology, e.g. time division multiple access (TDMA) as for example GSM, GPRS, D-AMPS or code division multiple access (CDMA) as for example CDMA2000, IS-95 or W-CDMA. Furthermore, it is widely believed that the next generation of Personal Communication Networks
15 (PCNs), employing low cost, pocket-sized, cordless telephones that can be carried comfortably and used to make or receive calls and communicate with interactive data bases like the Internet in the home, office, street, car, etc., will be provided by cellular carriers using the next generation digital cellular system infrastructure as for example W-CDMA, GPRS or EDGE. To provide an acceptable level of
20 equipment compatibility, standards have been created in various regions of the world. For example, analogue standards such as AMPS (Advanced Mobile Phone System), NMT (Nordic Mobile Telephone) and ETACS and digital standards such as D-AMPS (e.g., as specified in EIA/TIA-IS-54-B and IS-136) and GSM (Global System for Mobile Communications adopted by ETSI) have been promulgated to
25 standardise design criteria for radio communication systems. Once created these standards tend to be reused in the same similar form, to specify additional systems. For example, in addition to the original GSM system, there also exists the DCS1800, GPRS (General Package Radio Service), EDGE (Enhanced Data rate for GSM Evolution) (specified by ETSI), PCS1900 (specified by JTC in J-STD-
30 007); all of which are based on GSM.

The recent evolution in cellular communication services involves the adoption of additional frequency bands for use in handling mobile communication

5 services, e.g., for Personal Communication Services (PCS). Taking the U.S. as an example, the Cellular hyperband is assigned two frequency bands (commonly referred to as the A frequency band and the B frequency band) for carrying and controlling communications in the 800 MHz region. The PCS hyperband, on the other hand, is specified in the United States to include six different frequency
10 bands (A, B, C, D, E, F) in the 1900 MHz region. Thus, eight frequency bands are now available in any given service area of the U.S. to facilitate communication services. Certain standards have been approved for the PCS hyperband (e.g., PCS1900 (J-STD-136)), while others have been approved for the Cellular hyperband (e.g., D-AMPS (IS-136)).

15 Each one of the frequency bands specified for the Cellular and the PCS hyperbands is allocated a plurality of traffic channels and at least one access or control channel. The control channel is used to control or supervise the operation of the mobile station by means of information transmitted or received from the mobile stations. Such information may include incoming call signals, outgoing call
20 signals, page signals, page response signals, location registration signals, voice channel assignments, maintenance instructions, hand-over, and cell selection or reselection instructions as a mobile station travels out of the radio coverage of one cell and into the radio coverage of another cell. The control and voice channels may operate using either analogue modulation or digital modulation.

25 The signals transmitted by a base station in the downlink over the traffic and control channels are received by mobile or portable terminals, each of which has at least one antenna. Historically, portable terminals have employed a number of different antennas to receive and transmit signals over the air interface. For example, monopole antennas mounted perpendicularly to a conducting surface have
30 been found to provide good radiation characteristics, desirable drive point impedances and relatively simple construction. Monopole antennas can be created in various physical forms. For example, rod or whip antennas have frequently been

5 used in conjunction with portable terminals. For high frequency applications where an antenna's length is to be minimised, another choice is the helical antenna.

As described above, it is commercially desirable to offer portable terminals which are capable of operating in widely different frequency bands, e.g., bands
10 located in 900 MHz region, 1800 MHz region, 1900 MHz region and 2100 MHz region. Accordingly, antennas which provide adequate gain and bandwidth in all above frequency bands will need to be employed in the near future.

For example, U.S. Patent No. 4 572 595 describes a dual-band antenna having a sawtooth-shaped conductor element. The dual band antenna is tuned to
15 two different frequency bands. The antenna design in this patent is relatively insufficient since it is so physically close to the chassis of the mobile phone.

Japanese patent No. 6-37531 discloses a helix, which contains an inner parasitic metal rod. In this patent, the antenna can be tuned to dual resonant frequencies by adjusting the position of the metal rod. Unfortunately, the bandwidth
20 for this design is too narrow for use in cellular communications.

Dual-band, printed, monopole antennas are known in which dual resonance is achieved by the addition of a parasitic strip in close proximity to a printed monopole antenna. While such an antenna has enough bandwidth for cellular communications, it requires the addition of a parasitic strip. Moteco AB in Sweden has designed a coil matching dual-band whip antenna and coil antenna, in
25 which dual resonance is achieved by adjusting the coil-matching component ($1/4\lambda$ for 900 MHz and $1/2 \lambda$ for 1800 MHz). This antenna has relatively good bandwidth and radiation performances and a length in the order of 40 mm. A non-uniform helical dual-band antenna which is relatively small in size is disclosed in
30 copending, commonly assigned U.S. Patent Application No. 08/725 507, entitled "Multiple Band Non-Uniform Helical Antennas".

5 Presently, antennas for radio communication devices, such as mobile phones, are mounted directly on the phone chassis. However, as the size and weight of portable terminals continue to decrease, the above-described antennas become less advantageous due to their size. Moreover, as the functionality of these future compact portable terminals increases, the need arises for built-in miniature
10 antennas, which are capable of being resonant at multiple frequency bands.

Conventional built-in antennas currently in use in mobile phones include microstrip antennas and planar inverted-F antennas. Microstrip antennas are small in size and light in weight. The planar inverted-F antenna (PIFA) has already been implemented in a mobile phone handset, as described by Q.Kassim, "Inverted-F
15 Antenna for Portable Handsets", IEE Colloquium on Microwave filters and Antenna for personal Communication systems, pp. 3/1-3/6, Feb. 1994, London, UK. More recently, Lai et al has published a meandering inverted-F antenna (WO 96/27219). This antenna has a size, which is about 40 % of that of a conventional PIFA antenna.

20 Figures 1 and 2 illustrate the conventional planar patch antenna compared to the meandering inverted-F antenna described in Lai et al. The conventional planar patch antenna of Figure 1 has both size and length equal to, for example, a quarter wavelength of the frequency to which the antenna is made resonant. The conventional planar antenna also has a width W . The meandering inverted-F antenna, il-
25 lustrated in Figure 2, also has a length equal to a quarter wavelength of the resonant frequency and a width equal to W ; however, the size of the meandering inverted-F antenna is reduced to about 40 % of the size of the conventional planar patch antenna. This reduction in size is attributable to the antenna's meandering shape.

30 However, as mobile phones become smaller and smaller, both conventional microstrip antennas and PIFA antennas are still too large to fit the future small phone chassis. In copending U.S. Patent Application No. 09/112 366, enti-

5 tled "Miniature Printed Spiral Antenna for Mobile Terminals", a printed spiral built-in antenna with a matching post was proposed. The size of the antenna was reduced to 20- 30 % of the conventional PIFA antenna (less than 1/10 of the wavelength) thereby making it suitable for future mobile phones.

10 In addition to a reduced antenna size, next generation mobile phones will require the capability to tune to many frequency bands for cellular, wireless local area networks. In copending U.S. Patent Application No. 09/112 152, entitled "Twin Spiral Dual Band Antenna", a multiple band, built-in antenna was proposed which is suitable for future phones. The built-in antenna comprises two spiral conductor arms, which are of different lengths, and capable of being tuned to different
15 frequency bands. In order to increase the bandwidth of the antenna, a resistor loading technique is introduced. In another copending U.S. Patent Application No. 09/212 259, entitled "Printed Multi Band Antenna", a built-in patch antenna is provided which includes patch elements of different sizes and capable of being tuned to different frequency bands as can be seen in Figure 3.

20 A drawback with the above described antennas is that they are still too large and they have problems tuning to multiple frequency bands while simultaneously having a broad bandwidth in each of these multiple frequency bands.

The object of the present invention is to overcome this drawback.

25 **Summary of the invention**

The above object is achieved by means of a communication device in a radio communication system, and a built-in antenna as claimed in claims 1, 22, 46 and 59.

30 Thanks to the interaction between the parasitic element and the main radiator according to claims 1 and 22, the antenna gets a very broad bandwidth at the higher frequencies.

5 In a preferable embodiment as claimed in claim 8, the main radiator is folded into two radiating elements, wherein one of the elements is folded approximately 180 degrees in relation to the other element. Thanks to the folding of the antenna the resonance at the higher frequency bands could be decreased in the frequency spectrum.

10 In another preferable embodiment of the invention, the parasitic element of the antenna is arranged in the vicinity of, and in parallel with the main radiator achieving a good interaction between the parasitic element and the main radiator.

In yet another embodiment according to claim 12, the ground pin of the parasitic element is arranged in close vicinity of the feeding pin of the main radiator achieving good matching and tuning of the antenna.

15 The main radiator containing the two radiating elements and the parasitic element are preferably arranged on a substrate (plastic or ceramic), said substrate being mounted on a Printed Circuit Board (PCB) as is claimed in claim 17.

20 In another preferable embodiment of claims 21, 45, 58 and 69, the folded built-in PIFA is attached to the back cover of the mobile phone in order to increase the antenna bandwidth by increasing the distance between the radiator and the printed circuit board of the phone.

Other characteristics of the invention are set out in the other dependent claims.

25 Brief description of the drawings

The present invention will now be described in more detail with reference to preferred embodiments of the present invention, given only by way of examples, and illustrated in the accompanying drawings in which:

30 Figure 1 illustrates a conventional built-in PIFA;

5 Figure 2 illustrates a built-in meandering inverted F-antenna;

Figure 3 illustrates another built-in PIFA;

Figure 4 illustrates a radio communication device in which the antenna of the present invention may be implemented;

10 Figure 5 illustrates a small-size folded PIFA antenna according to the present invention;

Figure 6 illustrates a small size folded PIFA antenna with a parasitic element;

Figures 7 and 8 illustrate simulation results of the antennas in Figures 5 and 6, respectively;

15 Figure 9 illustrates the mounting of the antennas in figures 5 and 6 on a Printed Circuit Board (PCB). And

Figure 10 illustrates a cross-sectional view of a mobile phone with the PCB and the antenna of the invention.

20 **Detailed description of embodiments of the invention**

Figure 4 illustrates an exemplary radio communication device 400 in which the built-in multiple band folded PIFA antenna of the present invention may be implemented. Communication device 400 includes a chassis 410 having a first interface 420, 440 for allowing the communication device to receive information
25 from the user and a second interface 430 for allowing the communication device to transfer information to the user. It should be realised that this first interface could be a microphone, a keypad, a touchpad, a radio-port, an IR-port, a computer-port and/or a Bluetooth-port. It should also be realised that the second interface could be for example a speaker, display, radio-port, computer-port, Bluetooth-port
30 etc. For example, the communication device according to the invention could be a

5 Coca-Cola vending machine receiving a radio/Bluetooth signal from a mobile phone requesting a purchase of a Coke, first interface, and sending an acknowledgement by radio or Bluetooth, second interface, to the same mobile phone when the purchase has been completed. Preferably the communication device 400 is a mobile telephone with a microphone opening 420 and a speaker opening 430 located next to the position of the mouth and the ear, respectively, of the user. A keypad 440 allows the user to interact with the mobile telephone, e.g., by inputting a telephone number to be dialled. The mobile phone 400 also includes the folded PIFA antenna with a parasitic element 450 according to the present invention, the details of which will be described below. However, it should be realised that the folded PIFA antenna according to Figure 5 without the parasitic element could be implemented in the mobile phone 400 achieving a good antenna performance.

The antenna of the present invention, which is to be implemented in the above discussed communication device, represents a folded grounded patch antenna (PIFA) with a grounded parasitic element. A parasitic element is not galvanically connected to the radiating antenna but is only connected to the ground plane. Thus, the radio signal feeded to the radiating antenna is capacitively coupled to the parasitic element. Consequently, the radiating antenna together with the parasitic element will due to this coupling resonate at another frequency band, e.g., the PCS band. The capacitive coupling of the parasitic element to the main antenna results in this case in three resonances, two of which can be adjusted to lie next to each other thus creating a broad resonance. The antenna size can be as small as 45 mm x 20 mm, and the height of the antenna over the ground plane could be as small as 8 mm. The antenna in the present invention has broad bandwidth at high band covering at least the DCS and the PCS band. The other resonance occurs at the GSM band. Consequently, the antenna is functional at, at least three frequency bands, i.e., GSM (880-960 MHz), DCS (1710-1880) and PCS (1850-1990).

Figure 5 discloses the geometry of a folded PIFA type antenna 500 without parasitic parts. In this specific embodiment the width W of the antenna 500 is approximately 45 mm (about the same width as the Printed Circuit Board, PCB) and the length is about 20 mm. The height of the radiating part (first part) 500 is about 8 mm over the PCB. The width of the slot between the radiating arms (first and second element) 510, 520 in the radiating part 500 is approximately between 1 and 3 mm. It should be realised that the length of the arms 510, 520 could be different in order to get a better matching or tuning. A dielectric substrate could be positioned between the radiating part and the PCB, which will be described more in detail with reference to figure 9. The feeding pin 530 and the ground pin 540 of the folded PIFA antenna 500, 510, are connected to the receiver/transmitter of the communication device 400 and the PCB-ground of the communication device 400, respectively. The radiating part 500 is folded into two elements, a first element 510 and a second element 520. The first element 510 comprises the ground pin 540 and the feeding pin 530, respectively. The second element 520 comprises the open end 570 of the antenna 500. The open end 570 could arbitrarily be bent down towards the PCB, wherein the bent part 570 of the second element could form an almost perpendicular angle in relation to the second element 520. The second element 520 of the first part 500 is bent since it must have a specific electrical length to be made resonate at a certain frequency. However, the width W of the PCB defines the physical width W of the antenna 500, 600. Thus, to bend the open end of the second element 570 is an advantageous way to increase the electrical length of the antenna and to improve the matching of the antenna without changing the physical width W . The first and the second element have approximately the same width as the PCB. The second element 520 of the radiating part is folded approximately 180 degrees in relation to the longitudinal axis of the first element 510. It has been empirically tested that by folding the radiating part, it is possible to decrease the resonance frequency. It has also been empirically verified that by selecting the right width and length of different parts of the folded elements 510, 520

5 and the right width of the slot 550 between the first and the second element of the radiating part, it is possible to tune the antenna to the desired frequencies. The antenna in figure 5 can be tuned to GSM/DCS or GSM/PCS frequencies. Unfortunately, the bandwidth at the high band, i.e., the DCS/PCS band, is too small to cover both the DCS and PCS without using a switching circuit.

10 Figure 7 discloses VSWR plot of the folded PIFA antenna without the parasitic element according to figure 5. As can be seen from this figure the antenna 500 is tuned to be operational at two frequency bands (GSM/DCS or GSM/PCS). The bandwidth at the higher frequency bands is too small to cover both DCS and PCS simultaneously.

15 The radiation properties of an antenna are determined by a number of different factors, one of which is the VSWR-value. VSWR (Voltage Standing Wave Ratio) has values between 1 and infinity. VSWR indicates the amount of interference between two opposite travelling waves in the transmission line feeding the antenna and describes the rate of the matching of the antenna to the desired im-
20 pedance (usually 50 Ω). One of the waves is the source feeding while the other is the reflection from the antenna back into the transmission line. The objective is to minimise this reflection. The maximum VSWR of infinity occurs when the reflected wave has the same intensity as the incident one, i.e., the whole signal is reflected and no power is provided at the radiating element 500, 510, 520, 600. The
25 minimum VSWR of 1 occurs when the antenna is perfectly matched, i.e., no power is reflected and all power is transmitted to the radiator 500, 510, 520, 600. One usually designs the antenna to have a VSWR of less or equal to 2.5 of the desired frequencies.

30 Figure 6 discloses the geometry of the antenna 500, 600 according to the invention. The radiating part, i.e., the first part 500, of the antenna in this figure is the same as the radiating part 500, 510, 520 in figure 5. However, in order to increase the bandwidth at high band a parasitic element 600 (second part) is ar-

5 ranged in parallel to the radiating part, 510, or more specifically in parallel to the first element 510 of the radiating part 500. The parasitic element 600 has a main part 630 with an open end and is grounded at the other end 610. The main part 630 of the parasitic element 600 could have a bent portion 620 at its open end. This bent portion 620 towards the PCB could form an almost perpendicular angle in
10 relation to the main part 630. The main part 630 of the parasitic element 600 is bent since it must have a specific electrical length to be made resonate at a certain frequency. However, the width W of the PCB defines the physical width W of the parasitic antenna 600. Thus, to bend the open end of the main part 620, 630 is an advantageous way to increase the electrical length of the parasitic antenna 600
15 (second part) and to improve the matching of the same antenna without changing the physical width W. The ground pin 610 of the parasitic element is placed in the close vicinity of the feeding pin 530 of the main radiator 500. The introduction of the parasitic element 600 results in an additional resonance, which can be tuned to occur at a frequency near the higher frequency band (DCS) of the main radiator
20 500. These two higher frequencies merge together building one broad resonance. The parasitic element 600 (second part) is capacitively connected to the radiating part 500, which will make it resonate at a higher frequency band, i.e., the PCS band. The length L of the parasitic element 600 is approximately given by the formula: $L = \lambda_3/4$, where λ_3 is the wavelength of the frequency to which the para-
25 sitic element is tuned, in this case the PCS band. However, it should be realised that the λ_3 could be the wavelength of an arbitrary frequency. The main radiating part 500 (first part) with its radiating arm 510 and 520 has a length L given approximately by the following formula: $L = \lambda_1/4 = 3*\lambda_2/4$, where λ_1 corresponds to the GSM frequency and λ_2 corresponds to the DCS band when the antenna is
30 folded. It should be realised that the above formula should in this case be used for the folded antenna. By folding the antenna the resonance frequency in the higher frequency bands f_2 , λ_2 is decreased in the frequency spectrum reaching the DCS band. For the skilled man it is obvious that λ_1 and λ_2 could be the wavelengths of

5 arbitrary frequencies. The physical length L of the main radiating antenna 500 is approximately 9 cm. The parasitic element 600 is positioned approximately in parallel to the first element 510 of the main radiator 500. The distance between the first element and the parasitic element is approximately 1 to 3 mm. This distance can be arbitrarily varied depending on the tuning and the matching of the antenna.

10 The distance between the ground pin of the parasitic element 600 and the feeding pin of the main radiator 500, 510 is approximately 0.5-1 mm. This distance can of course be arbitrarily varied to achieve adequate matching of the impedance of the antenna and tuning of the frequency bands. The matched antenna should have an almost fully resistive impedance of about 50 Ω .

15 As mentioned above the overall dimensions of the folded PIFA antenna with the parasitic element are 45 mm x 20 mm x 8 mm. With these dimensions the antenna is capable of operating at GSM, DCS and PCS frequency bands. As already mentioned the position of the feeding pin and the ground pins as well as the lengths of the main and the parasitic elements 510, 520, 600, can be used for

20 matching and tuning the antenna 500, 600. A larger height of the antenna influences the bandwidth of the antenna, and a larger height results in a larger bandwidth. The height of the antenna 500, 600 in figure 6 is about 8 mm above the ground plane (PCB-ground) which is enough for an antenna operating at GSM, DCS and PCS. It should be realised that the height of the antenna arbitrarily could

25 be increased to cover an even broader spectrum, i.e., UMTS band (1920-2170 MHz). One skilled in the art will of course appreciate that other combinations of frequency bands may be implemented without departing from the spirit of the scope of the present invention. For example, other possibilities of low and high bands could include GSM+DCS+WCDMA, GSM+PCS+WCDMA, or any other

30 combination of lower and higher frequency bands. The antenna of the present invention has small dimensions and can easily be integrated in a mobile terminal 400. For every mobile phone 400 it has to be retuned because the PCB ground as

5 well as the back cover of the phone can influence the tuning to the appropriate frequency band.

The VSWR plot of the antenna in figure 6 can be seen from figure 8. Thanks to the parasitic element 600 the VSWR plot has a new resonance at 2.05 GHz. The VSWR values are also very good and are less than 2 for all desired frequency bands, GSM, DCS and PCS.

The antenna design according to figure 6 was first simulated using Zeland IE3D software package. This software package is based on a moment method for solving electromagnetic field problems. After satisfying results had been achieved, a prototype was built to verify simulation results. As can be seen from figure 9, the antenna 500 with the parasitic element 600 was attached to a dielectric substrate 900 with a relative dielectric permittivity constant of approximately 1. The substrate had a height of approximately 8 mm and thus the distance between the antenna 500, 600 and the PCB ground 560 was about 8 mm. The achieved bandwidth was slightly less than the one indicated by the simulations. Gain measurements showed that gain values were about the same as for stubby antennas at GSM frequencies and 1-2 dB better at DCS/PCS frequencies. According to the above simulation the bandwidth at GSM frequencies is approximately 100MHz and the bandwidth at DCS/PCS frequencies is approximately 300MHz.

As can be seen from figure 9, the folded planar inverted PIFA antenna 500 with the parasitic element 600 according to the present invention is attached to the top of a substrate 900. The antenna 500, 600 is mounted at the edge of the PCB 560, which provides for better radiation efficiency and bandwidth. In addition, the PCB space requirement for the built-in antenna 500, 600 is minimised due to its small size. Thus, the substrate is normally placed and fastened on the upper part of the PCB 560. Consequently, when the PCB is mounted in the mobile phone 400 the antenna 500, 600 is arranged in the upper region 450 of the phone 400. The substrate could be made of a material with an arbitrary dielectric constant de-

5 pending on the bandwidth etc. The ground pins 540, 610 and the feeding pin 530 of the antenna 500, 600 are connected to PCB ground 560 and receiver/transmitter 450, respectively, through the substrate 900. The antenna 500, 600 could for example be etched or printed on a ceramic or plastic substrate 900, which is suitable for mounting on a PCB. The substrate could also be replaced by dielectric legs
10 keeping the antenna 500, 600 at an appropriate distance from the PCB. The antenna 500, 600 could also have been cut out and then placed on the above substrate, legs. The antenna could also be placed on the PCB 560 without using substrate or legs, which implies that there is an air space between the radiator 500, 600 and the PCB 560.

15 Figure 10 discloses another preferable way to attach the antenna 500, 600 to the phone 400, 450. Figure 10 is cross-sectional view of a mobile phone, the PCB 560 and the antenna 500, 600. In this embodiment, the antenna is attached to the back cover 1000 of the phone 450. The antenna seen in a section view is connected to the receiver/transmitter and the PCB 560 in the normal way by means of
20 the feeding pin 530 and the ground pins 540, 610. Since the antenna is fastened to the back cover 1000 the whole height from the PCB 560 to the back cover can be used for increasing the bandwidth of the antenna as described earlier.

It should be realised that the antenna 500 without the parasitic element 600 (Figure 5) could be attached and implemented in a phone chassis in the same way
25 as the antenna described in connection with Figure 6.

One skilled in the art will appreciate that an increase in the area or thickness of the substrate 900 or antenna size or a decrease in the value of the dielectric constant results in an increase of the bandwidth, which can be achieved. Moreover, the bandwidth also depends on the size and location of the slots in the antenna
30 500. It is obvious for the skilled man that the above-described antenna 500, 600 could have an arbitrary two-dimensional or three-dimensional structure.

5 It should be emphasised that the concept "comprises/comprising" when used in this specification is taken to specify the presence of stated features, integers, steps or components but does not preclude the presence or addition of one or more other features, integers, steps, components or groups thereof.

 It would be appreciated by those of ordinary skill in the art that the present
10 invention could be embodied in other specific forms without departing from the spirit or essential character thereof. The presently disclosed embodiments are therefore considered in all respects to be illustrative and not restrictive. The scope of the invention is indicated by the appended claims rather than the foregoing description, and all changes which come within the meaning and range of equivalence
15 lence thereof are intended to be embraced therein.

Claims

5
1. A communication device (400) for use in a radio communication system, said device having a first interface (420, 440) for allowing said communication device to receive information from a user; a second interface (430) for allowing the communication device to transmit information to said user, **characterised by a**
10 built-in multiple band antenna (450, 500, 600) comprising a first part (500) tuned to at least a first and a second frequency band and a second part (600) electro-magnetically interacting with said first part (500), said second part (600) being tuned to at least third frequency band when electro-magnetically interacting with said first part (500).

15 2. A communication device as claimed in claim 1, **characterised in that** said first interface (420, 440) having a microphone and/or a keypad for receiving information from said user and said second interface (430) having a speaker for transmitting information to said user.

20 3. A communication device as claimed in claims 1 or 2, **characterised in that** said second part (600) is galvanically separated from said first part.

4. A communication device as claimed in any of the preceding claims, **characterised in that** said second part having a ground pin (610) connected to a ground plane (560) and a main element (630) with an open end (620).

25 5. A communication device as claimed in any of the preceding claims, **characterised in that** said first part (500) having a ground pin (540) connected to the ground plane (560) and a feeding pin (530) connected to a transmitter/receiver (400, 450).

30 6. A communication device as claimed in claim 5, **characterised in that** said first part is folded to form a first element (510) and a second element (520), said first element (510) having the ground pin (540) and the feeding pin (530) and said second element having an open end (570).

5 7. A communication device as claimed in claim 6, **characterised in** that the second element (520) is folded at least 90 degrees in relation to the longitudinal axis of the first element (510).

 8. A communication device as claimed in any of claims 6 or 7, **characterised in** that the second element (520) is folded approximately 180 degrees in relation to the longitudinal axis of the first element (510).
10

 9. A communication device as claimed in claims 6 to 8, **characterised in** that said first (510) and second element (520) of said first part (500) and said main element (630) of said second part (600) are spaced apart from ground (560), preferably by means of a dielectric substrate, legs or a plastic, ceramic substrate.

15 10. A communication device as claimed in any of the preceding claims, **characterised in** said second part (600) is arranged in close vicinity of and in parallel with the first part (500).

 11. A communication device as claimed in any of claims 6 to 10, **characterised in** that said main element (630) of the second part (600) is arranged in close vicinity of, and in parallel with the first element (510) of the first part (500).
20

 12. A communication device as claimed in any of claims 6 to 11, **characterised in** that said ground pin (610) of the second part (600, 630) is placed in close vicinity of the feeding pin (530) of the first part (500, 510).

 13. A communication device as claimed in any of claims 6 to 12, **characterised in** that said open end (570) of the first part's (500) second element (520) is bent down towards the ground plane of a PCB to increase its electrical length without affecting its physical width W.
25

 14. A communication device as claimed in any of claims 6 to 13, **characterised in** that said open end (620) of the second part's main element (630) is bent down towards the ground plane of a PCB to increase its electrical length without affecting its physical width W.
30

5 15. A communication device as claimed in any of claims 6 to 14, **characterised in** that a slot between the first and the second element of the first part (500) has a width of approximately 1 to 3 mm.

 16. A communication device as claimed in any of claims 6 to 15, **characterised in** that the first and the second element of the first part (500), and the second part (600) can have different lengths and widths to achieve an arbitrary tuning to a specific frequency.

10 17. A communication device as claimed in any of claims 4 to 16, **characterised by** a substrate (900) with a predetermined thickness, onto which said first part (500) and second part (600) are mounted, said substrate (900) being mounted
15 on a PCB (560) containing said ground plane.

 18. A communication device as claimed in claim 17, **characterised in** that said substrate is a ceramic or plastic substrate.

 19. A communication device as claimed in any of claims 1 to 18, **characterised in** that said first frequency band corresponds to GSM, said second frequency band corresponds to DCS and said third frequency band corresponds to PCS.

20 20. A communication device as claimed in any of claims 1 to 19, **characterised in** that the length of the built-in multiple band antenna (500, 600) is approximately 20 mm, the width is approximately 45 mm and the height over ground
25 is approximately 8 mm.

 21. A communication device as claimed in any of claims 1 to 20, **characterised in** that said antenna (500, 600) is attached to a back cover (1000) of said communication device (450).

 22. A built-in antenna for a radio communication device (400, 450), **characterised by** a first part (500) tuned to at least a first and a second frequency band
30 and a second part (600) electro-magnetically interacting with said first part (500),

- 5 said second part (600) being tuned to at least a third frequency band when electromagnetically interacting with said first part (500).

23. A built-in antenna as claimed in claim 22, **characterised in** that said second part (600) is galvanically separated from said first part (500).

- 10 24. A built-in antenna as claimed in claims 22 or 23, **characterised in** that said second part having a ground pin (610) connectable to a ground (560) and a main element (630) with an open end (620).

- 15 25. A built-in antenna as claimed in any of claims 22 to 24, **characterised in** that said first part (500) having a ground pin (540) connectable to a ground plane (560) and a feeding pin (530) connectable to a transmitter/receiver (400, 450).

26. A built-in antenna as claimed in claim 25, **characterised in** that said first part is folded to form a first element (510) and a second element (520), said first element (510) having the ground pin (540) and the feeding pin (530) and said second element having an open end (570).

- 20 27. A built-in antenna as claimed in claim 26, **characterised in** that the second element (520) is folded at least 90 degrees in relation to the longitudinal axis of the first element (510).

- 25 28. A built-in antenna as claimed in claims 26 or 27, **characterised in** that the second element (520) is folded approximately 180 degrees in relation to the longitudinal axis of the first element (510).

29. A built-in antenna as claimed in any of claims 26 to 28, **characterised in** that said first (510) and second element (520) of said first part (500) and said main element (630) of said second part (600) are spaced apart from ground (560), preferably by means of a dielectric substrate, legs or a plastic, ceramic substrate.

5 30. A built-in antenna as claimed in any of claims 22 to 29, **characterised**
in said second part (600) is arranged in close vicinity of and in parallel with the
first part (500).

 31. A built-in antenna as claimed in any of claims 26 to 30, **characterised**
in that said main element (630) of the second part (600) is arranged in close vicin-
10 ity of, and in parallel with the first element (510) of the first part (500).

 32. A built-in antenna as claimed in claim 26 to 31, **characterised in that**
said ground pin (610) of the second part (600, 630) is placed in close vicinity of
the feeding pin (530) of the first part (500, 510).

 33. A built-in antenna as claimed in any of claims 26 to 32, **characterised**
15 in that said open end (570) of the first part's (500) second element (520) is bent
down towards the ground plane (560) of a PCB to increase its electrical length
without affecting its physical width W.

 34. A built-in antenna as claimed in any of claims 26 to 33, **characterised**
in that said open end (620) of the second part's main element (630) is bent down
20 towards the ground plane (560) of a PCB to increase its electrical length without
affecting its physical width W.

 35. A built-in antenna as claimed in any of claims 26 to 34, **characterised**
in that a slot between the first and the second element of the first part (500) has a
width of approximately 1 to 3 mm.

25 36. A built-in antenna as claimed in any of claims 26 to 35, **characterised**
in that the first and the second element of the first part (500), and the second part
(600) can have different lengths and widths to achieve an arbitrary tuning to a spe-
cific frequency.

 37. A built-in antenna as claimed in any of claims 26 to 36, **characterised**
30 by a substrate (900) with a predetermined thickness, onto which said first part

- 5 (500) and second part (600) are mounted, said substrate (900) being mounted on a PCB (560) containing said ground plane.

38. A built-in antenna as claimed in claim 37, **characterised in that** said substrate is a ceramic or plastic substrate.

39. A built-in antenna as claimed in any of claims 22 to 38, **characterised**
10 **in that** said first frequency band corresponds to GSM, said second frequency band corresponds to DCS and said third frequency band corresponds to PCS.

40. A built-in antenna as claimed in any of claims 22 to 39, **characterised**
in that the length of the built-in multiple band antenna (500, 600) is approximately 20 mm, the width is approximately 45 mm and the height over ground plane (560)
15 is approximately 8 mm.

41. A built-in antenna as claimed in any of claims 22 to 40, **characterised**
in that said antenna having an arbitrary two or three-dimensional shape.

42. A built-in antenna as claimed in claims 37 or 38, **characterised in that**
said PCB (560) containing the substrate (900) with the first and second part (500,
20 600) is mounted on the chassis (410, 450) inside a radio communication device (400).

43. A built-in antenna as claimed in any of claims 22 to 42, **characterised**
in that the first part (500) has a length corresponding to the first frequency to
which it is made resonant, and to the second frequency to which it is made reso-
25 nant, said second frequency being approximately twice as high as said first frequency.

44. A built-in antenna as claimed in any of claims 22 to 43, **characterised**
in that the second part (600, 630) has approximately a length corresponding to $\frac{1}{4}$
wavelength of the third frequency λ_3 to which it is made resonant.

5 45. A built-in antenna as claimed in any of claims 22 to 44, **characterised** in that said antenna is attachable to a back cover (1000) of a mobile communication device (400, 450).

 46. A communication device (400) in a radio communication system, said device having a first interface (420, 440) for allowing said communication device
10 to receive information from a user; a second interface (430) for allowing the communication device to transmit information to said user, **characterised by** a built-in multiple band antenna (450, 500) comprising a first part (500) tuned to at least a first and a second frequency band, said first part being folded to form a first element (510) and a second element (520), said first element having a ground pin
15 (540) connected to a ground plane (560) and a feeding pin (530) connected to a receiver/transmitter (400, 450) and said second element having an open end (570).

 47. A communication device as claimed in claim 46, **characterised in** that said first interface (420, 440) having a microphone and/or a keypad for receiving information from said user and said second interface (430) having a speaker for
20 transmitting information to said user.

 48. A communication device as claimed in claims 46 or 47, **characterised in** that said second element (520) is folded at least 90 degrees in relation to the longitudinal axis of the first element (510).

 49. A communication device as claimed in any of claims 46 to 48, **characterised in** that the second element (520) is folded approximately 180 degrees in relation to the longitudinal axis of the first element (510).
25

 50. A communication device as claimed in any of claims 46 to 49, **characterised in** that said open end (570) of the first part's (500) second element (520) is bent down towards the ground plane (560) of a PCB to increase its electrical
30 length without affecting its physical width W.

5 51. A communication device as claimed in any of claims 46 to 50, **characterised in** that a slot between the first and the second element of the first part (500) has a width of approximately 1 to 3 mm.

 52. A communication device as claimed in any of claims 46 to 51, **characterised in** that the first and the second element of the first part (500) can have different lengths and widths to achieve an arbitrary tuning to a specific frequency.
10

 53. A communication device as claimed in any of claims 46 to 52, **characterised by** a substrate (900) with a predetermined thickness, onto which said first part (500) is mounted, said substrate (900) being mounted on a PCB (560) containing said ground plane.

15 54. A communication device as claimed in any of claims 46 to 53, **characterised in** that said first frequency band corresponds to GSM and said second frequency band corresponds to DCS or PCS.

 55. A communication device as claimed in any of claims 46 to 54, **characterised in** that the length of the built-in multiple band antenna (500, 510, 520) is approximately 20 mm, the width is approximately 45 mm and the height over
20 ground plane (560) is approximately 8 mm.

 56. A communication device as claimed in claims 53, **characterised in** that said PCB (560) containing the substrate (900) with the first part (500) is mounted on a chassis (410, 450) inside the communication device (400).

25 57. A communication device as claimed in any of claims 46 to 56, **characterised in** that the first part (500) has a length corresponding to the first frequency to which it is made resonant, and to the second frequency to which it is made resonant, said second frequency being approximately twice as high as said first frequency.

5 58. A communication device as claimed in any of claims 46 to 57, **characterised** in that said antenna (500, 600) is attached to a back cover (1000) of said communication device (400,450).

10 59. A built-in antenna for a radio communication device (400, 450), **characterised by** a first part (500) tuned to at least a first and a second frequency band, said first part being folded to form a first element (510) and a second element (520), said first element (510) having a ground pin (540) connectable to a ground plane (560) and a feeding pin (530) connectable to a receiver/transmitter (500, 540), and said second element having an open end (570).

15 60. A built-in antenna as claimed in claim 59, **characterised in** that the second element (520) is folded at least 90 degrees in relation to the longitudinal axis of the first element (510).

 61. A built-in antenna as claimed in claims 59 or 60, **characterised in** that the second element (520) is folded approximately 180 degrees in relation to the longitudinal axis of the first element (510).

20 62. A built-in antenna as claimed in any of claims 59 to 61, **characterised in** that said open (570) end of the first part's (500) second element (520) is bent down towards the ground plane (560) of a PCB to increase its electrical length without affecting its physical width W.

25 63. A built-in antenna as claimed in any of claims 59 to 62, **characterised in** that a slot between the first and the second element of the first part (500) has a width of approximately 1 to 3 mm.

30 64. A built-in antenna as claimed in any of claims 59 to 63, **characterised by** a substrate (900) with a predetermined thickness, onto which said first part (500) is mounted, said substrate (900) being mounted on a PCB (560) containing said ground plane.

5 65. A built-in antenna as claimed in any of claims 59 to 64, **characterised**
in that said first frequency band corresponds to GSM and said second frequency
band corresponds to DCS or PCS.

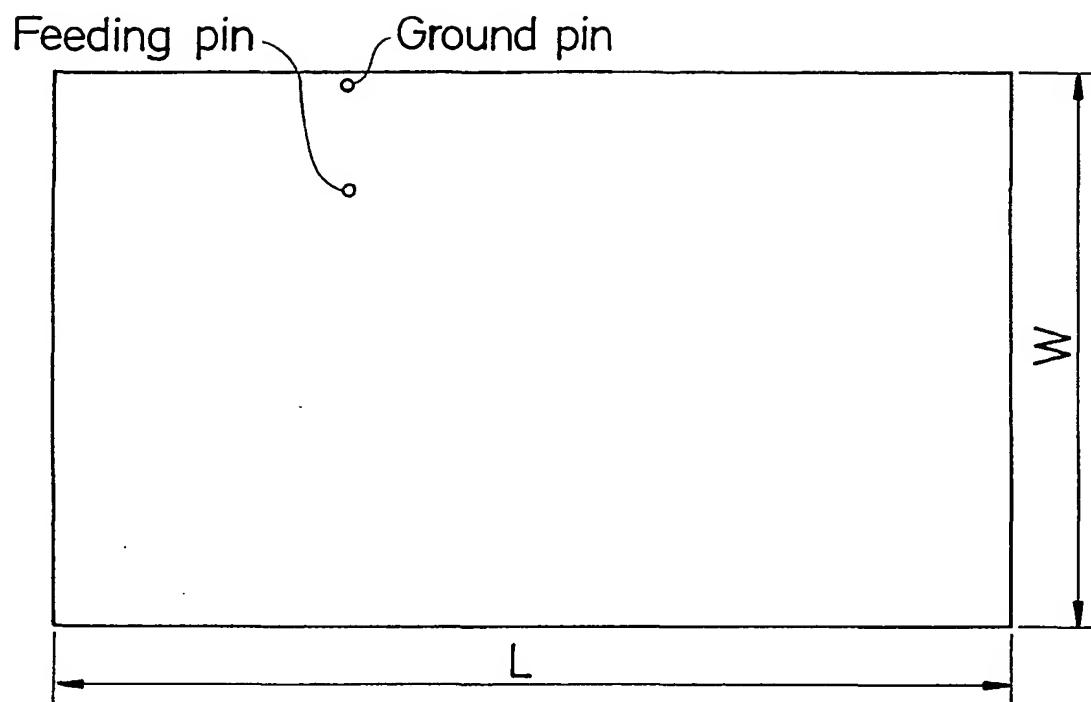
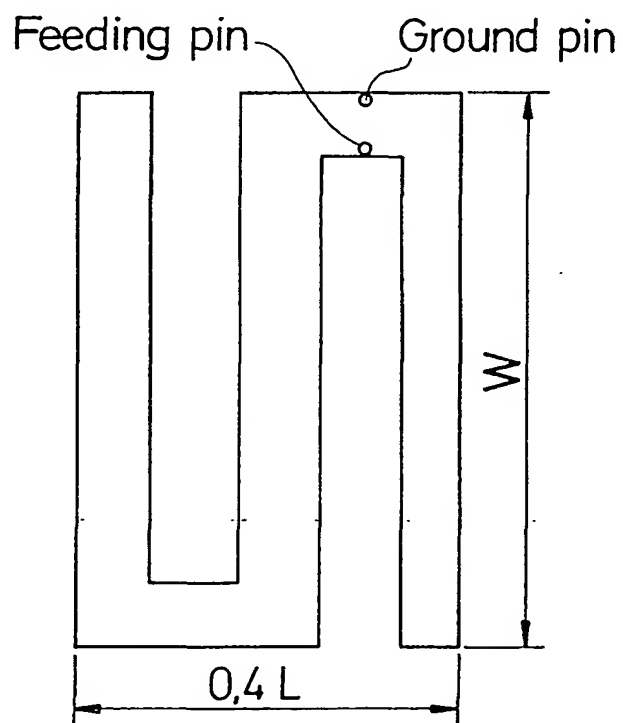
 66. A built-in antenna as claimed in any of claims 59 to 65, **characterised**
in that the length of the built-in multiple band antenna (500) is approximately 20
10 mm, the width is approximately 45 mm and the height over ground plane (560) is
approximately 8 mm.

 67. A built-in antenna as claimed in claim 64, **characterised in** that said
PCB (560) containing the substrate (900) with the first part (500) is mounted on
the chassis (410, 450) inside a radio communication device (400).

15 68. A built-in antenna as claimed in any of claims 59 to 67, **characterised**
in that the first part (500) has a length corresponding to the first frequency to
which it is made resonant, and to the second frequency to which it is made reso-
nant, said second frequency being approximately twice as high as said first fre-
quency.

20 69. A built-in antenna as claimed in any of claims 59 to 68, **characterised**
in that said antenna (500, 600) is attached to a back cover (1000) of a mobile
communication device (450, 400).

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*FIG. 1**FIG. 2*

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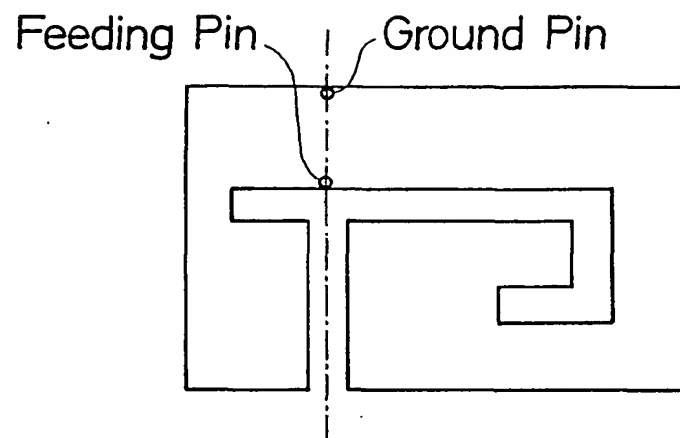


FIG. 3

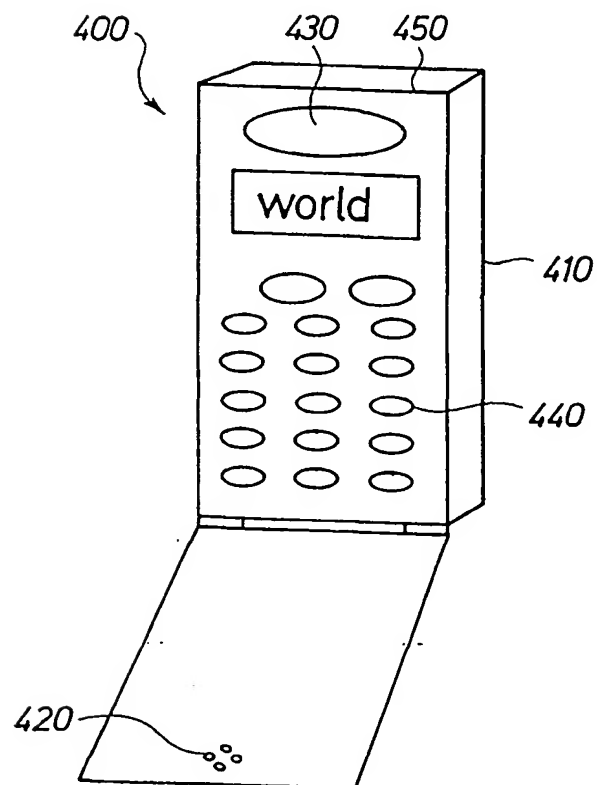
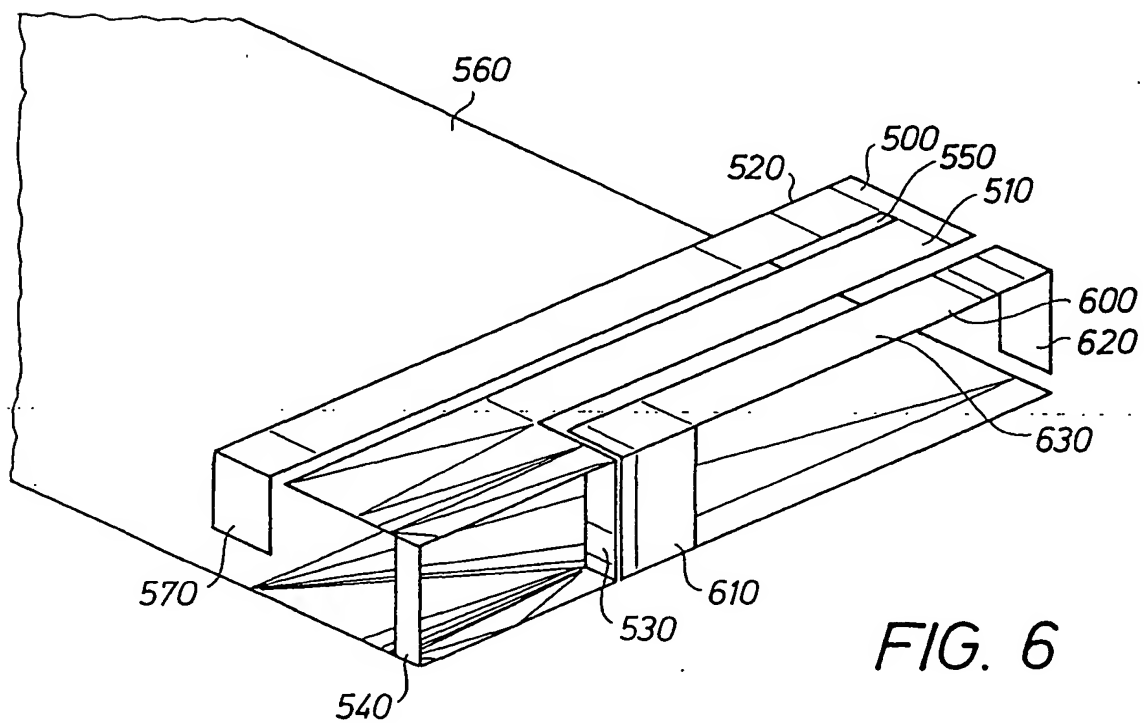
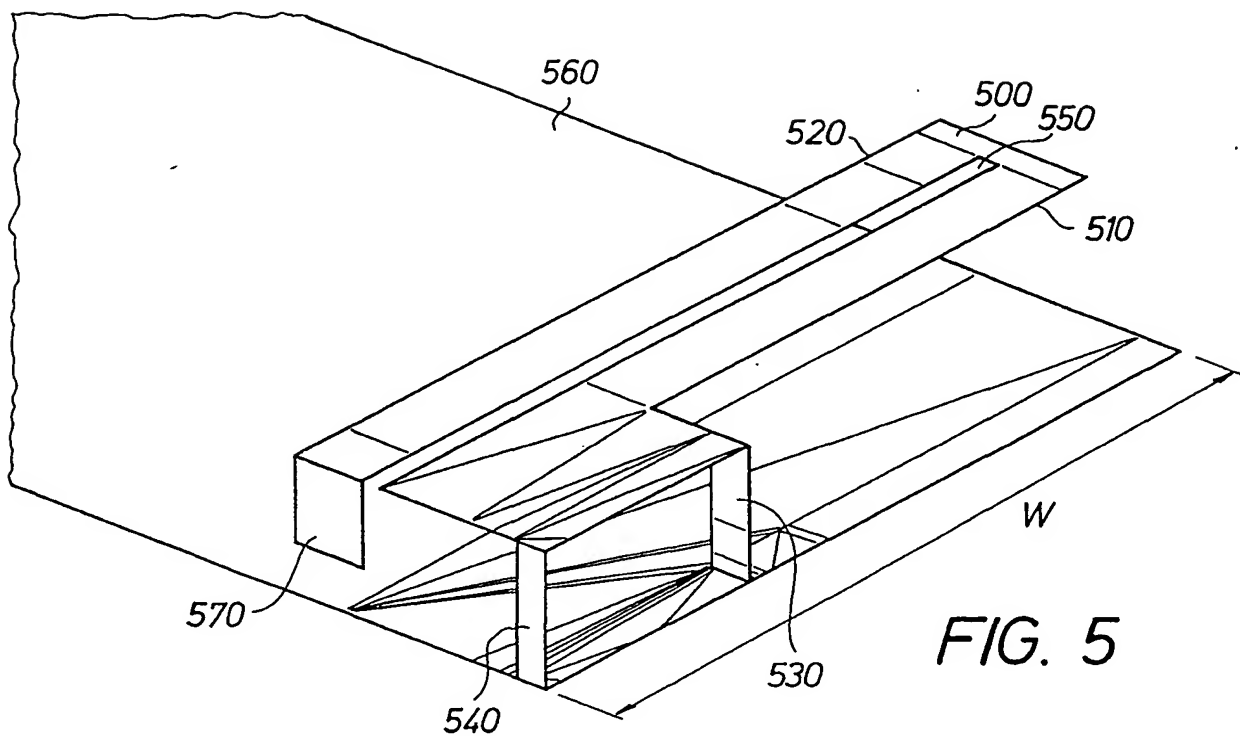


FIG. 4

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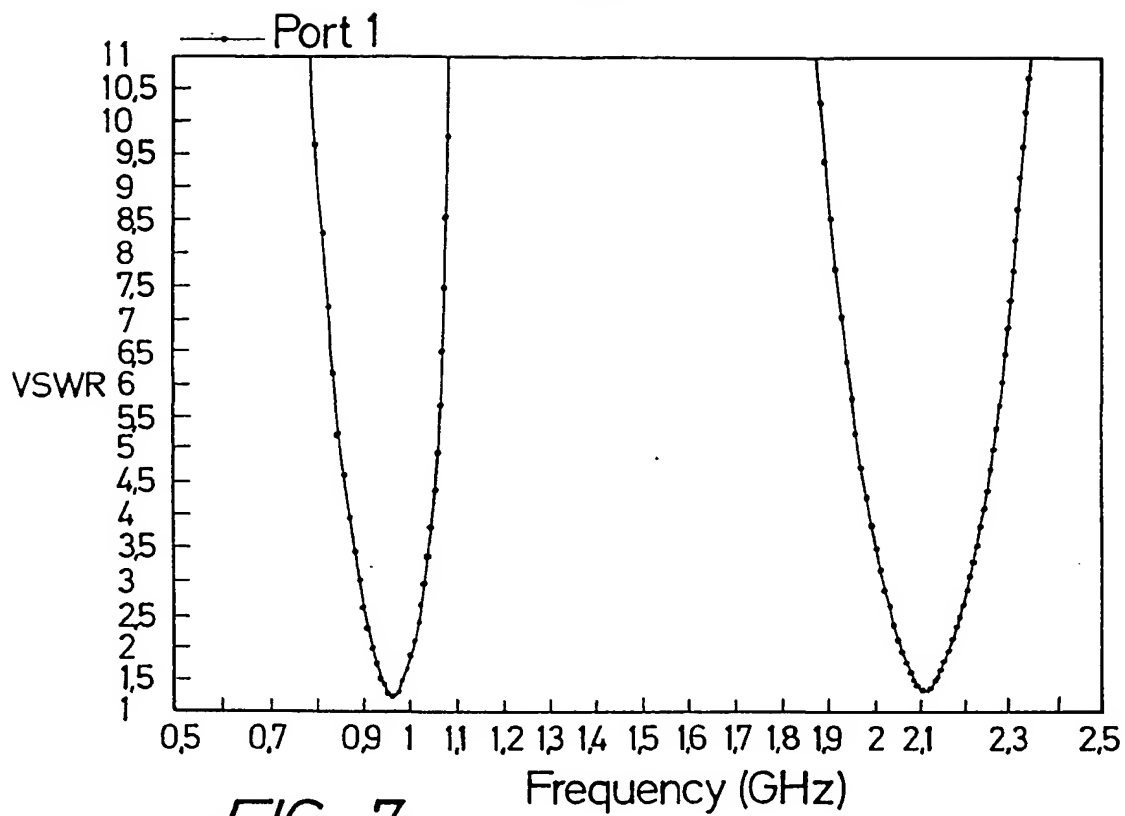


FIG. 7

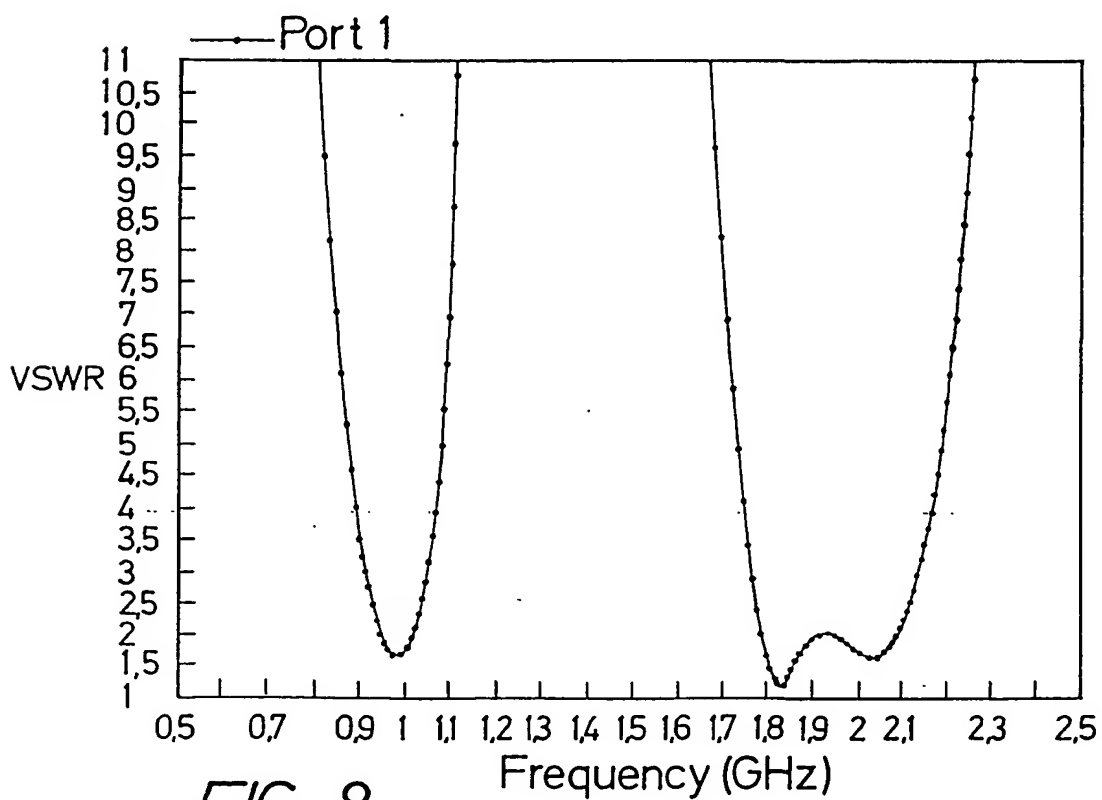


FIG. 8

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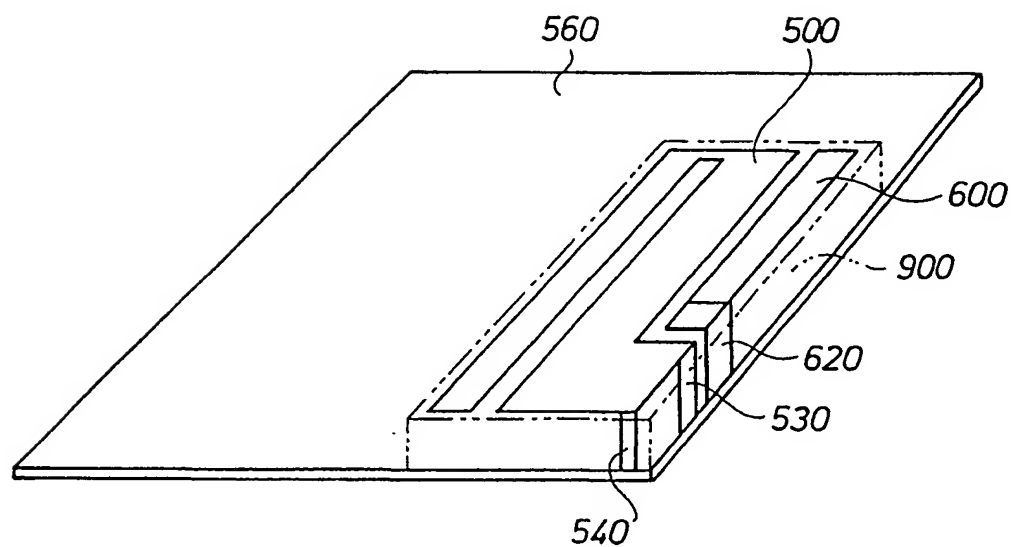


FIG. 9

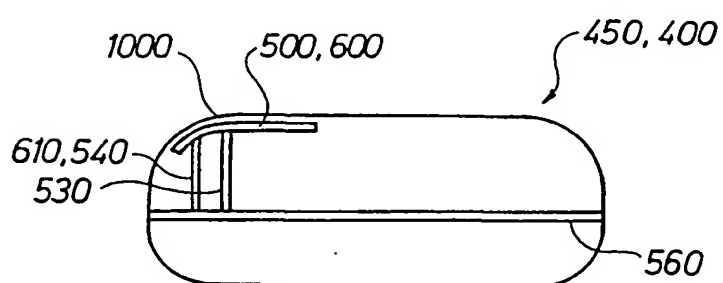


FIG. 10

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 01/01607

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: H01Q 1/24, H01Q 1/38, H01Q 5/00
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: H01Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-INTERNAL

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 10-93332 A (NIPPON ANTENNA CO LTD), 10 April 1998 (10.04.98), figures 3b,4 --	1-2,22
X	WO 9903168 A1 (ALLGON AB), 21 January 1999 (21.01.99), page 1, column 17 - line 22; page 3, line 30 - page 4, line 2; page 7, line 28 - page 8, line 6, figure 7b --	1-2,5-7,16, 19-22,25-27, 36,39-45
X	EP 1024552 A2 (SIEMENS AKTIENGESELLSCHAFT), 2 August 2000 (02.08.00), column 4, line 31 - column 5, line 38, figures 1-2,5, claims 1-7,14-17 --	1-45

☒ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed

"I" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

8 November 2001

Name and mailing address of the ISA/
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Date of mailing of the international search report

12-11-2001

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/SE 01/01607

C (Continuation). DOCUMENTS CONSIDERED 'TO BE RELEVANT'		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 6008762 A (NGHIEM, D.), 28 December 1999 (28.12.99), column 7, line 16 - line 38, figure 3	46-69
A	--	1-45
A	Patent Abstracts of Japan, abstract of JP 7-131234 A (NIPPON MEKTRON LTD), 19 May 1995 (19.05.95)	1-45
A	--	
A	WO 9844588 A1 (QUALCOMM INCORPORATED), 8 October 1998 (08.10.98), abstract	1-69
A	--	
A	ROWELL, Corbett R. et al. "A Compact PIFA Suitable for Dual-Frequency 900/1800-MHz Operation". IEEE transactions on antennas and propagation, April 1998, Vol. 46, No. 4, pp. 596-598, Figures 1-4	1-69
P,X	FR 2800920 A1 (ALCATEL SOCIETE ANONYME), 11 May 2001 (11.05.01), figures 1-4, abstract	46-69

INTERNATIONAL SEARCH REPORT

Information on patent family members

01/10/01

International application No.

PCT/SE 01/01607

Patent document cited in search report			Publication date	Patent family member(s)	Publication date
JP	10-93332	A	10/04/98	NONE	
WO	9903168	A1	21/01/99	AU 7560398 A	08/02/99
				AU 8365998 A	08/02/99
				CN 1261988 T	02/08/00
				CN 1262791 T	09/08/00
				EP 0995231 A	26/04/00
				EP 0996992 A	03/05/00
				JP 2001510288 T	31/07/01
				SE 511501 C	11/10/99
				SE 9702659 A	10/01/99
				WO 9903166 A	21/01/99
				EP 1071564 A	31/01/01
				SE 514021 C	11/12/00
				SE 9800899 A	19/09/99
				WO 9947365 A	23/09/99
EP	1024552	A2	02/08/00	NONE	
US	6008762	A	28/12/99	NONE	
WO	9844588	A1	08/10/98	AU 6584698 A	22/10/98
FR	2800920	A1	11/05/01	WO 0135492 A	17/05/01

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 01/01607

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see extra sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☒ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest.
- ☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 01/01607

Invention 1

A built-in antenna according to claims 22-45 and a communication device including such an antenna according to claims 1-21.

Invention 2

A built-in antenna according to claims 59-69 and a communication device including such an antenna according to claims 46-58.

The common technical features of invention 1 and invention 2 are a built-in antenna comprising a (first) part tuned to at least a first and a second frequency band. However, such an antenna is previously known from, e.g. US6008762. Therefore, invention 1 and invention 2 do not have common special technical features as required by PCT Rule 13.2.